INDOOR AIR QUALITY ASSESSMENT

Memorial Elementary School
125 Winn Street
Burlington, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
September 2004

Background/Introduction

At the request of parents and building occupants, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Memorial Elementary School (MES), 125 Winn Street, Burlington, Massachusetts. The IAQ assessment was prompted by reports of poor ventilation and general indoor air quality complaints.

On May 14, 2004, a visit was to conduct an indoor air quality assessment was made to this school by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Craig Robinson, Facilities Director, Burlington Public Schools, accompanied Mr. Holmes during the assessment.

The MES is a one-story brick building constructed in 1955. Windows, floors and portions of the roof have been replaced; all other equipment in the school is original. The school contains general classrooms, music room, art room, gymnasium, cafeteria, library, health suite and main office. Windows are openable throughout the building.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The MES houses approximately 260 kindergarten through fifth grade students and approximately 40 staff members. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in twenty of twenty-six areas surveyed, indicating inadequate ventilation in most areas of the school. It is also important to note that a number of classrooms had open windows, which can greatly reduce carbon dioxide levels. During the heating season, when exterior doors and windows are closed, the carbon dioxide levels would be expected to be higher.

Fresh air in classrooms is supplied by a unit ventilator (univent) system (Picture 1). A univent draws air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 2) and returns air through an air intake located at the base of the unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located on the top of the unit. The majority of univents were operating during the assessment; however, a few had been deactivated by occupants due to excessive noise. Obstructions to airflow, such as papers and books stored on univents and items in front of univent returns were seen in a number of classrooms (Picture 3). In order for univents to provide fresh air as designed, these units must remain free of obstructions and allowed to operate while rooms are occupied.

Exhaust ventilation in classrooms consists of wall-mounted grilles (Picture 4), which are powered by rooftop motors. The draw of air into these vents is controlled by a pull chain/louver system (Picture 4). Many of the pull chains and louvers were not operable or were missing. The exhaust system was not functioning or was drawing weakly in a number of areas surveyed, indicating that motors had been deactivated or were non-functional. In order to function properly the ventilation system must be restored to its original design by repairing/replacing control systems. A number of exhaust vents were also obstructed by tables, chairs, boxes and other items (Picture 5). As with the univents, in order to function properly, exhaust vents must be activated and remain free of obstructions. Without sufficient supply and exhaust ventilation, environmental pollutants can build up and lead to indoor air quality/comfort complaints.

In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 ppm. Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings ranged from 70 ^{o} F to 76 ^{o} F, which were within the BEHA comfort guidelines the day of the assessment. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. A number of temperature control complaints were reported. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents deactivated/obstructed, exhaust vents not operating).

Relative humidity measurements ranged from 41 to 54 percent, which were also within the BEHA comfort range. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A number of areas had water-damaged ceiling tiles, which is evidence of historic roof or plumbing leaks. In many cases these water damaged ceiling tiles were observed around skylights that had been sealed to prevent leakage (Picture 6). In classrooms, water damaged ceiling tiles are part of an interlocking system, which makes removal difficult. The ceiling tile system in hallways consists of drop ceilings, which are relatively easy to change. Water-damaged ceiling tiles can provide a source of mold growth and should be replaced after a water leak is discovered and repaired. No active leaks were reported in the school at the time of the assessment.

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detectable or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, the US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations the day of the assessment were measured at 83 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 54 to 96 $\mu g/m^3$. The elevated outdoor air particulate levels measured the day of the assessment (83 $\mu g/m^3$) may be attributed to exhaust emissions from automobile and bus traffic. The MES is located at the busy intersection of Winn and Center Streets, directly across from the Marshall Simonds Middle School. Where outdoor PM2.5 concentrations exceed the NAAQS, it is recommended that steps be taken to reduce pollutants in the indoor environment (e.g., use of filters that are more efficient) (ASHRAE, 1989). Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC measurements throughout the building were also ND.

Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While TVOC levels were ND, materials containing VOCs were present in the school. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Several other conditions that can affect indoor air quality were observed during the assessment. Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate and also make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Several areas contained window-mounted air conditioners. This type of air conditioner is normally equipped with filters, which should be cleaned or changed as per manufacturer's instructions to avoid the build up and re-aerosolization of dirt, dust and particulate matter.

Finally, in an effort to reduce noise from sliding chairs, tennis balls had been cut open and placed on chair legs (Picture 7). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998).

Conclusions/Recommendations

The conditions related to indoor air quality problems at the MES raise a number of issues. General building conditions, conditions of HVAC equipment and limited availability of replacement parts, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is required. This approach consists of **short-term** measures to improve air quality and **long-term** measures that require planning and resources to address the overall indoor air quality concerns adequately.

The following **short-term** measures should be considered for implementation:

1. Ensure all operable ventilation systems (supply and exhaust) throughout the building (e.g., classrooms, gym, auditorium) are operating continuously during periods of school occupancy.
2. Inspect exhaust motors and belts for proper function. Repair and replace as necessary.
3. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
4. Consult a ventilation engineer concerning re-balancing of the ventilation systems. Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994).
5. Ensure any roof/plumbing leaks are repaired. Replace any remaining water-stained ceiling tiles (for dropped ceilings). Examine the areas above and around these tiles for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.

6. Consider increasing the dust-spot efficiency of univent filters. Prior to any increase of filtration, each piece of air handling equipment should be evaluated by a ventilation engineer as to whether it can maintain function with more efficient filters.
7. Clean/change filters for window-mounted air conditioners as per the manufacture's instructions or more frequently if needed.
8. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
9. Consider discontinuing the use of tennis balls on chair legs.
10. Consider adopting the US EPA (2000b) document, *Tools for Schools*, in order to provide self-assessment and maintain a good indoor air quality environment at your building. The document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
11. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://www.state.ma.us/dph/beha/iaq/iaqhoFtme.htm.

The following **long-term measures** should be considered:

1. Contact an HVAC engineering firm for a ventilation systems assessment. Based on the age, physical deterioration and availability of parts for ventilation components, such an evaluation is necessary to determine the operability and feasibility of repairing/replacing the equipment.

2. Remove ceiling tiles using adequate containment methods. Replacement of ceiling tiles may also involve glues that contain VOCs. In order to minimize occupant exposure, repairs should be done while the building is unoccupied.

References

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Picture 1

Vintage 1950s Classroom Univent, Note Flowering Plants Near Air Diffuser

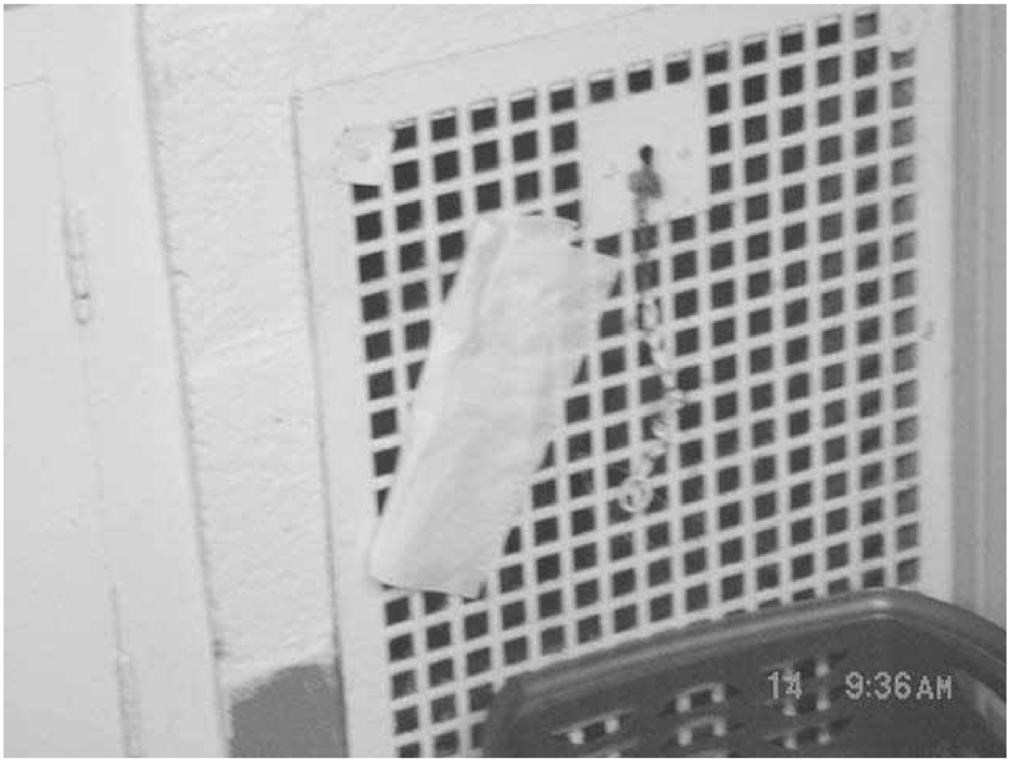
Picture 2

Univent Air Intake

Picture 3

Univent Obstructed on Top and in Front by Various Items

Picture 4

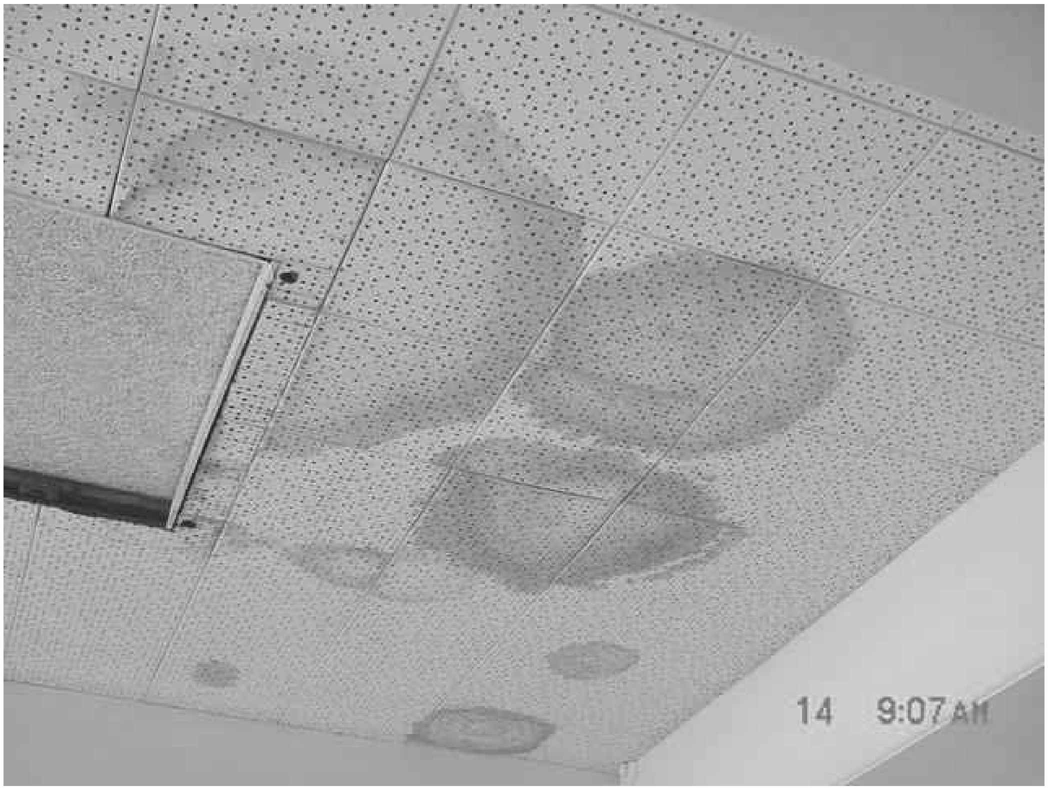


Classroom Exhaust Vent, Note Pull Chain

Picture 5

Classroom Exhaust Vent Obstructed by Curtain around Sink and Other Items

Picture 6



Water-Damaged Interlocking Ceiling Tiles

Picture 7

Tennis Balls on Chair Legs in Classroom

Memorial Elementary School **Indoor Air Results**

25 Winn Street, Burlington, MA **May 14, 2004**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background (outdoors)	59	57	385	ND	ND	83	-	-	-	-	Atmospheric Conditions: cloudy, winds light & variable
104	70	54	926	ND	ND	81	19	Y	Y	Y	DO, exhaust vent obstructed, historic WD on CT (20+) around skylights, DEM, CF
105	72	51	1152	ND	ND	79	17	Y	Y	Y	DO, WD CT (10+), UV obstructed by furniture, CF
106	71	47	873	ND	ND	77	17	Y	Y	Y	DO, UV obstructed by furniture, exhaust vent blocked by items, CF
107	73	49	1235	ND	ND	60	14	Y	Y	Y	DO, exhaust vent–no draw, plants, DEM, CF
103	74	46	932	ND	ND	76	16	Y	Y	Y	DO, exhaust vent-no draw, WD CT around skylights, TB, CF
108	74	45	1132	ND	ND	67	16	Y	Y	Y	DO, UV and exhaust vent obstructed, CF

ppm = parts per million parts of air
CT = ceiling tile
AD = air deodorizer
AP = air purifier
CD = chalk dust

µg/m3 = microgram per cubic meter
WD = water damage
DEM = dry erase marker
DO = door open
PC = photocopier

UV = univent
CF = ceiling fan
PF = personal fan
TB = tennis balls
UF = upholstered furniture

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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									Supply	Exhaust	
102	73	44	878	ND	ND	81	21	Y	Y	Y	DO, 3 windows open, UV and exhaust vent obstructed, exhaust vent-weak, CF-on
115	72	45	1062	ND	ND	69	0	Y	Y	Y	17 occupants gone 5 min, DO, plants on UV, TB, 15 WD CT, CF
Music Room	72	46	643	ND	ND	70	1	Y	Y	Y	DO, exhaust damper-closed, opened by Mr. Robinson, exhaust vent obstructed, 10 WD CT, CF
109 Art	72	41	519	ND	ND	73	0	Y	Y	Y	DO, CF, exhaust vent-no draw and obstructed, TB
101	74	47	969	ND	ND	78	14	Y	Y	Y	TB, UV obstructed by furniture, exhaust vent-no draw and obstructed
116	72	48	1906	ND	ND	54	17	Y	Y	Y	DO, DEM, CF, Exhaust vent-no draw and obstructed, TB
114	73	48	1569	ND	ND	67	18	Y	Y	Y	DO, window open, 7 WD CT, DEM

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117	74	46	1643	ND	ND	59	8	Y	Y	Y	DO, 2 windows-mounted AC units, airflow obstructed by book stacks, UV obstructed by furniture, plants on UV, exhaust vent obstructed, DEM, 20+ WD CT<
113	74	46	1643	ND	ND	58	14	Y	Y	Y	DEM, DO, exhaust vent-no draw-pull chain-missing, aquarium, UV obstructed by furniture
Gym	74	41	619	ND	ND	73	1	N	Y	Y	Air handling unit-noisy
Main Office	74	44	945	ND	ND	76	2	Y	N	N	Window AC, photocopier-operating
Principal's Office	74	44	893	ND	ND	89	0	Y	N	N	Window AC
Nurse	76	43	927	ND	ND	73	2	Y	N	N	Window AC

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120	75	44	1520	ND	ND	63	13	Y	Y	Y	DO, window AC, exhaust vent-obstructed, DEM, CF
112	73	44	1136	ND	ND	79	12	Y	Y	Y	DO, window open, DEM, TB, UV and exhaust vent obstructed, CF
119	74	45	1226	ND	ND	70	19	Y	Y	Y	DO, aquarium, AC, pull chain for exhaust-painted shut, CF
Cafeteria	73	43	753	ND	ND	96	75	Y	Y	Y	Windows open, air handling unit-off
Teacher's Lounge	72	44	639	ND	ND	79	0	Y	N	N	Window AC
ESL	72	43	700	ND	ND	88	1	N	N	N	Sectioned off the cafeteria

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